JONES DAY

51 LOUISIANA AVENUE, N.W. • WASHINGTON, D.C. 20001.2113

TELEPHONE: +1.202.879.3939 • FACSIMILE: +1.202.626.1700

DIRECT NUMBER: (202) 879-3630
BOLCOTT@JONESDAY.COM

June 29, 2017

VIA ELECTRONIC FILING

Marlene H. Dortch
Secretary
Federal Communications Commission
445 12th Street S.W.
Washington D.C. 20554

Re: Oral *Ex Parte* Notice
GN Docket No. 14-177, IB Docket Nos. 15-256 and 97-95;
RM-11664 and 11773; and WT Docket No. 10-112

Dear Ms. Dortch:

On June 27, 2017, representatives of The Boeing Company ("Boeing") met with staff of the Federal Communications Commission ("Commission") to discuss the above-referenced proceedings and Boeing's continuing technical studies demonstrating the ability for spectrum sharing between the Upper Microwave Flexible Use Service ("UMFUS") and next-generation broadband satellite communications systems in the 37.5-40.0 GHz band ("39 GHz"). The substance of the meeting tracked closely with the attached PowerPoint presentation. A list of meeting attendees is provided as Attachment 1 to this letter.

Thank you for your attention to this matter. Please contact the undersigned if you have any questions.

Sincerely,

Bruce A. Olcott
Counsel to The Boeing Company

Attachments

ATTACHMENT 1
June 27, 2017 Ex Parte Meeting Attendees

Wireless Telecommunications Bureau

- John Schauble
- Joel Taubenblatt

Simon Banyai

- Janet Young
- Catherine Schroeder
- Jeffrey Tignor
- Matthew Pearl (by phone)
- Steve Buenzow (by phone)
- Tim Hilfiger (by phone)

International Bureau

- Jose Albuquerque
- Robert Nelson
- Chip Fleming
- Jennifer Gilsenan
- Diane Garfield
- Kal Krautkramer

Office of Engineering and Technology

- Ira Keltz
- Michael Ha
- Bahman Badipour
- Anthony Lavarello
- Barbara Pavon
- Martin Doczkat
- Nicholas Oros

Boeing Participants

- Jeffrey Trauberman
- Robert Vaughan
- Robert Hawkins
- Bruce Olcott

ATTACHMENT 2
Meeting Presentation

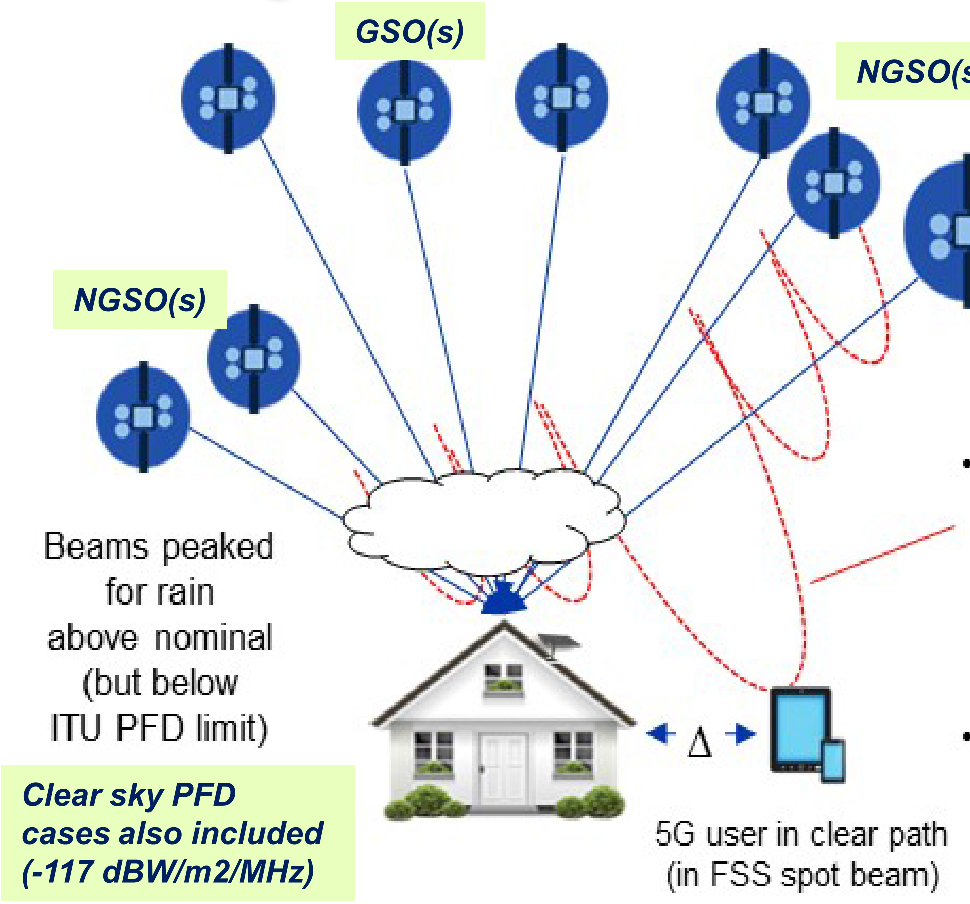
Spectrum Frontiers FNPRM 37/39 GHz FSS Downlink Spectrum Sharing Discussion

27 June 2017

TOPICS

- **Response to Straight Path's multipath analysis comments**
- **LEO antenna patterns and contributions from all satellites**
- **EPFD and link degradations into "omni"-like antennas**
- **EPFD update with probabilistic rain fade**
- **Spectrum sharing impacts for wide 5G deployments**
  - CONUS-wide link degradation/EPFD assessment
  - System Capacity impacts – multi-beam base stations, broad area deployments
- **EPFD regulatory framework – Update**
- **Summary and Conclusions**

Extended EPFD methodology models full range of FSS sharing with UMFUS



- Victim 5G receiver antenna pattern reduces total interference from different satellite paths
- "Equivalent PFD" is less than simple aggregate combined

$$ePFD = 10\log_{10}\left(\sum_{k=1}^{Nsats} 10^{\frac{(G_r^k(\theta_k,\phi_k)+PFD_k)}{10}}\right) - (G_{r-pk})$$

N_{sats} = Number of total NGSO satellites radiating beams at the particular ground point
PFD_k = incident PFD of the kth NGSO satellite at the ground point in dBW/m2/MHz
$G_r^k(\theta_k,\phi_k)$ = Gain of the 5G victim receiver antenna in the direction toward the kth NGSO satellite, in dBi
G_{r-pk} = Peak gain of the 5G victim receiver (usually G_r (0,0) at boresight), in dBi

$$INR_{dB} = [ePFD + G_{r\text{-}pk} - 10\log_{10}(4\pi/\lambda^2) - k - T_r]$$

$$(I/N)_{deg} = 10\log_{10}(10^{(INR/10)}+1)$$

λ = wavelength in m; λ ~= ($0.3/F_c$) where F_c is in GHz

G_r = Isotropic gain of the 5G receiver in the direction of the arriving PFD signal, in dBi

K = Boltzmann's constant, -228.6 dB W/K-Hz

T_r = 5G receiver noise temperature in dB/K, calculated as $10\log_{10}(T_b+290*[10^{(NF/10)}-1])$ where T_b= background temperature (usually 290K for terrestrial background and/or rain) and NF = noise figure of the 5G receiver in dB

5G receiver points beams random, at satellite, or at user/base station LOS

- **ePFD methodology correctly models impacts for FSS/UMFUS sharing**
- **Expanded analysis includes multipath, 5G pointing, clear sky PFDs, and multiple GSO+NGSO systems**

Multipath Analysis Clarifications

All areas modeled using OSM database included representative buildings

- Densities from 100 to 1000 buildings per km^2

Rooftops modeled on all structures aligned with the buildings with random pitch angles

Number of possible reflections analyzed ranged from one million per time step to more than two billion per time step in some denser scenes

Number of valid reflections traced ranged from 20 to 80 in scenes modeled

- Generally represented 3 to 4 times the number of operating satellites visible

Accurate, realistic scenarios with detailed results (few assumptions or approximations)

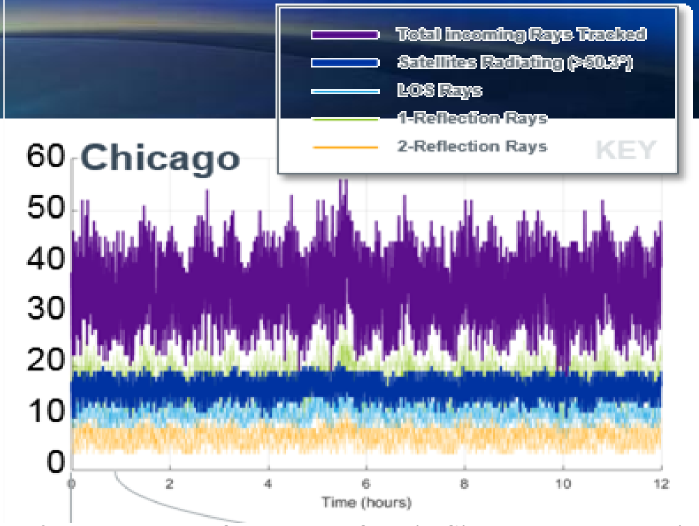
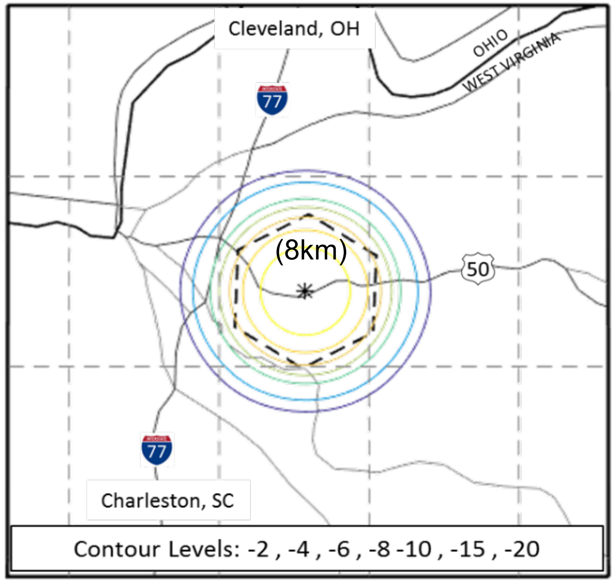


Figure 3 - Examples of Number of Valid Signal Paths Resulting in Multipath Interference Scenarios (Number of NGSO Satellites = 10 to 15)

Metro Area	Environment	Neighborhood	Building Density (#/km^2)
Atlanta	Suburban	Morningside	231
Atlanta	Urban	Midtown	202
Chicago	Suburban	Evanston	90
Chicago	Urban	Rogers Park	401
Houston	Suburban	Lawndale	520
Houston	Urban	Downtown	82
Los Angeles	Suburban	Westchester	570
Los Angeles	Urban	Financial District	130
Miami	Suburban	Kendale Lakes	319
Miami	Urban	Downtown	195
Miami	Urban	Burlingame	51
New York	Suburban	Highlands	1040
New York	Suburban	White Plains	477
New York	Urban	Times Square	140
New York	Urban	Financial District	212
New York	Urban	Brooklyn	1096
San Francisco	Suburban	San Mateo	308
San Francisco	Urban	Financial District	370
Seattle	Suburban	Laurelhurst	649
Seattle	Urban	Downtown	219
Washington DC	Suburban	Foxhall Crescent	555
Washington DC	Urban	Thomas Circle	685

Table 1 - Building Density for 22 Scenes and 9 Cities in Multipath Modeling

LEO Satellite Beams Sizes and Responses



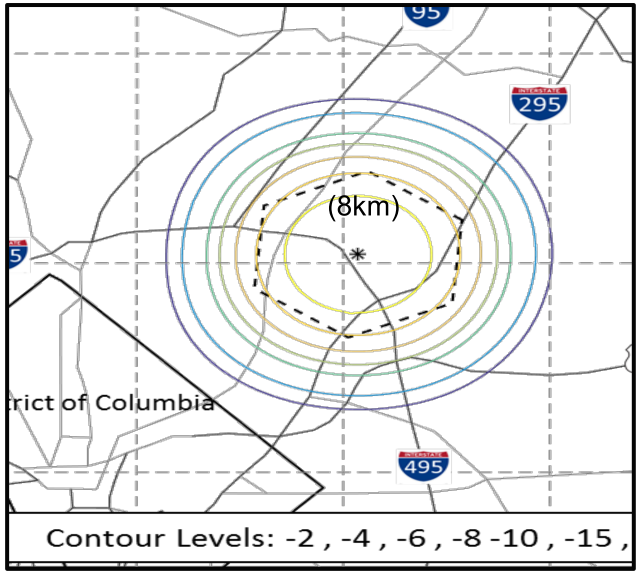
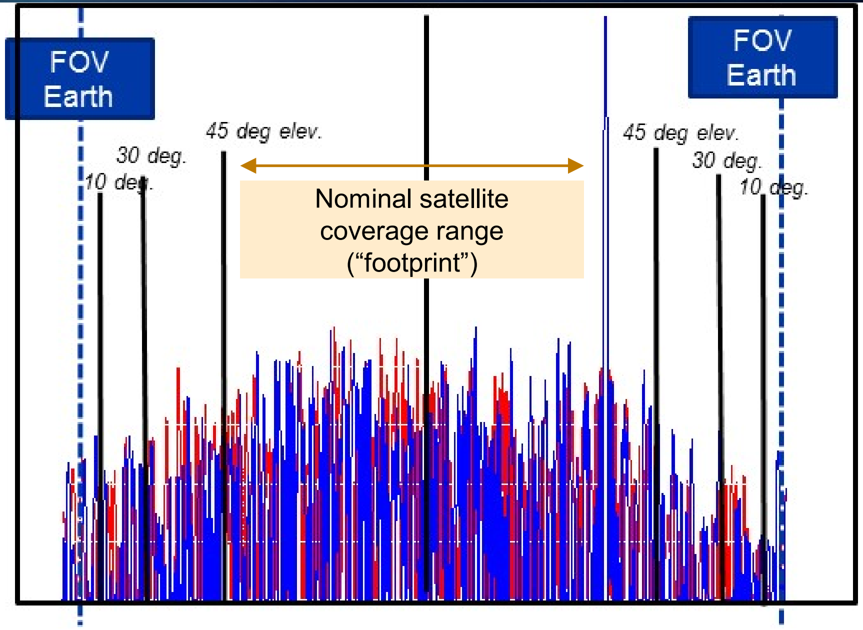
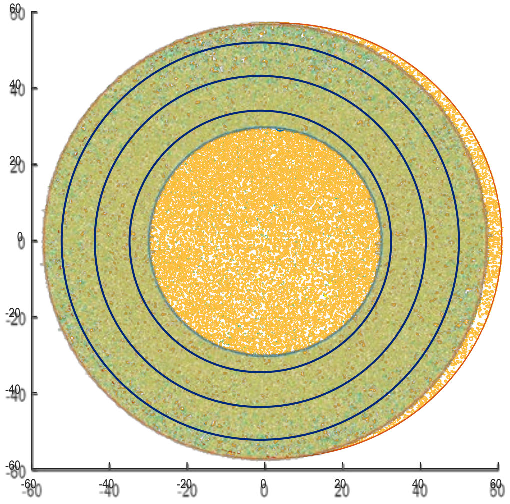


Figure II-3 (Ohio) **Figure II-5 (DC/Baltimore)**

8km beam patterns from FCC Application



Average Sidelobe Levels: -30 to 40 dB



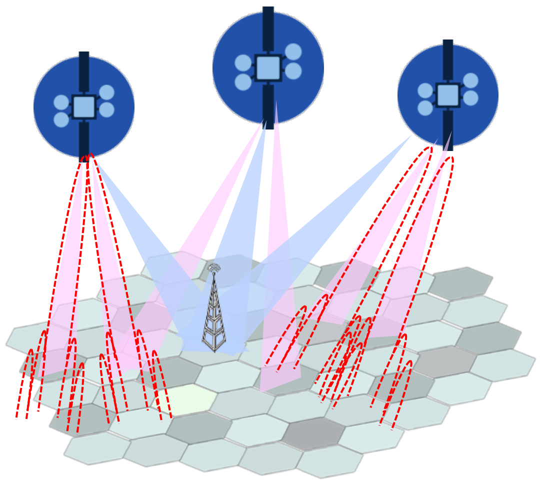
Circular contours shown at
50 deg elevation angle
45 deg elevation angle
30 deg elevation angle
10 deg elevation angle

- **V-band LEO system can operate narrow beam patterns, or adjust shapes/sizes to wider beams**
- **To maintain good system performance, beams have low sidelobes outside of the desired coverage width**
- **Sidelobes stay low and are even further reduced outside the intended footprint**

LEO beam patterns can provide narrow beamwidth and low sidelobe emissions outside of intended coverage

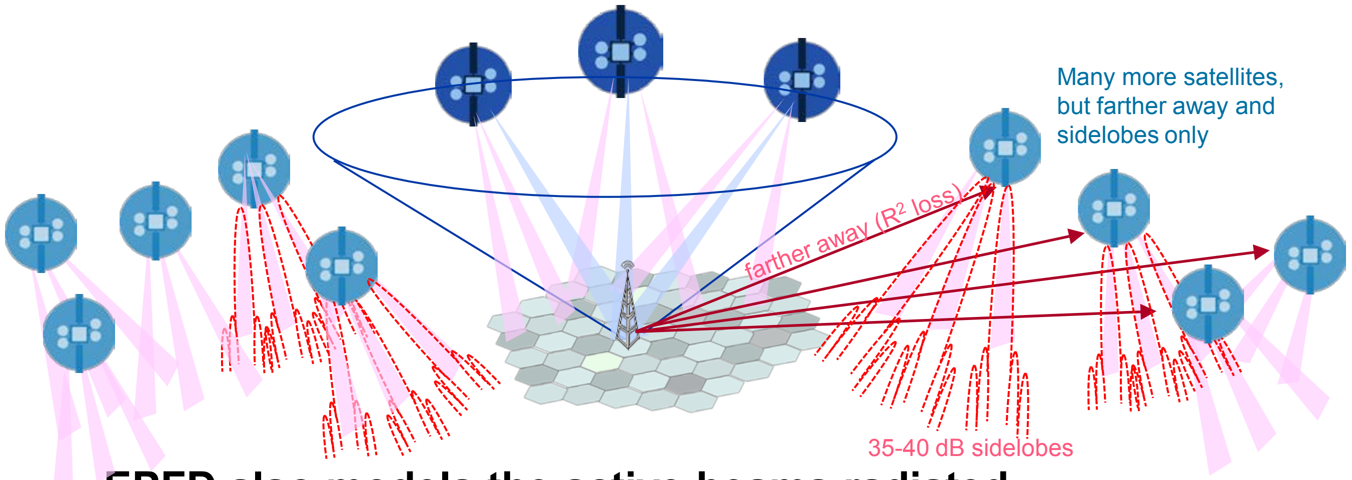
Impacts of Radiated Beams from All Visible Satellites

All Beams from the satellites providing service to the earth location are modeled



- **EPFD approach models active beams radiated from separate satellites at a single location on the earth**
- **Other beams radiated from the same satellite are either operating on different frequency bands, OR are steered away from the earth location**
- **The aggregate PFD of all the other beams from the same satellite produces the system's internal interference or C/I ratio, which is typically ~20 dB**
- **The entire additional impact due to internal C/I of 20 dB is 0.04 dB**

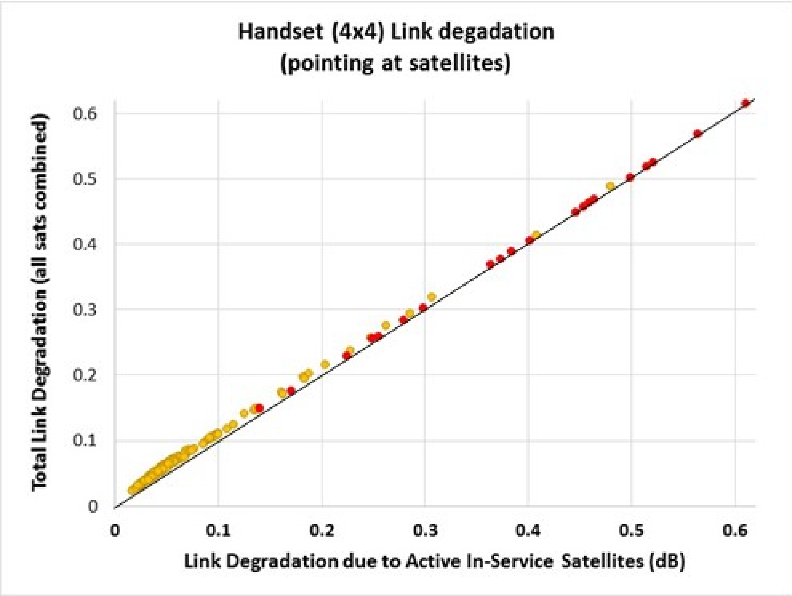
All Beams from the satellites NOT providing service to the earth location but visible over the horizon (>5 deg) are modeled

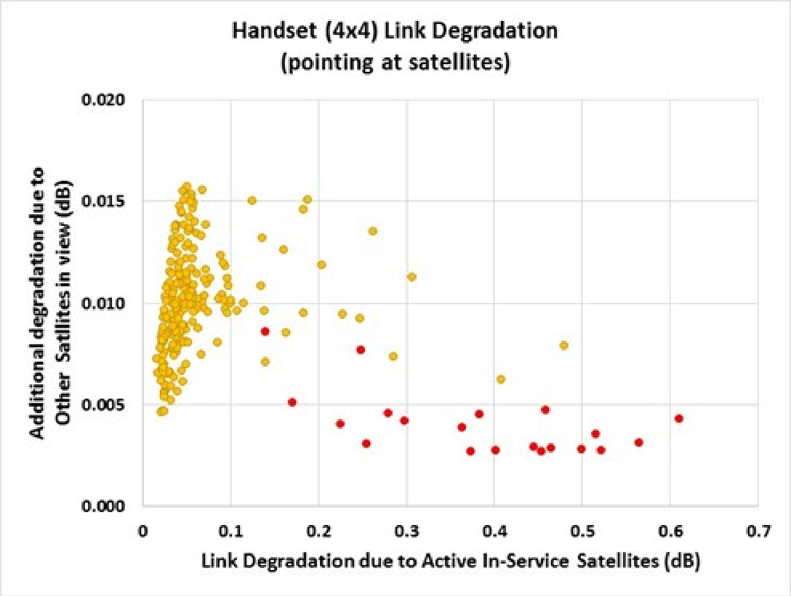


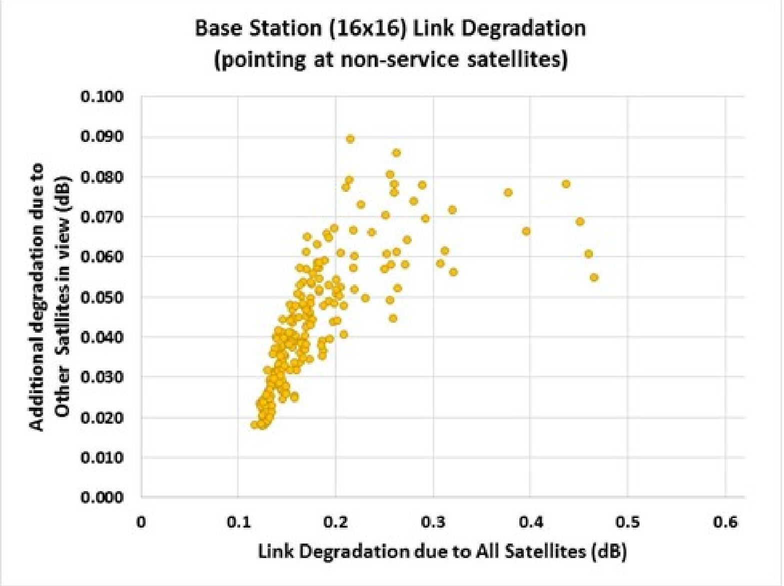
- **EPFD also models the active beams radiated from other satellites not serving the intended area**
- **These beams are not radiated towards the intended earth location, and all of the satellite's energy is seen through the antenna sidelobes (similar to internal C/I)**
- **In addition, the slant range to the satellite greatly attenuates the emissions of the low-elevation angle satellites**
- **The aggregate PFD of all other beams from all other satellites visible over the horizon above 5 degrees is modeled**
  - At 5 degrees and below, slant range losses, atmospheric scintillation, and blockage provide significantly more attenuation

All radiated emissions from all visible satellites are appropriately included in proposed EPFD regulations

Example of EPFD and Link Degradation from Active Servicing Satellites and Other Satellites In-view







Contributions from satellites servicing other areas are minimal (0.02-0.07 dB) and are included in EPFD models and regulations

New York area location
Up to 20 satellites serving NYC area (Red)
221 other satellites not serving NYC (Yellow)

Note: range loss only considered. Additional atmospheric and scintillation losses at low elevation angles are considerable

FSS 37/39 GHz Sharing with UMFUS

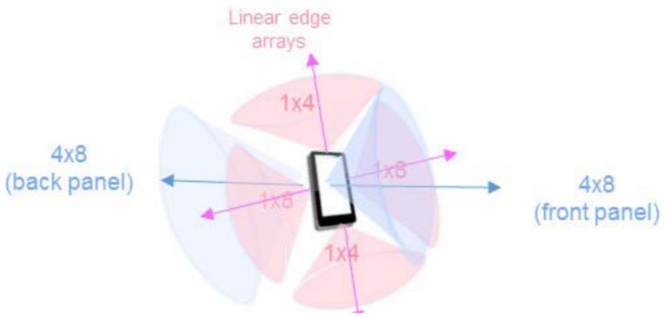
- Low-gain and "omni" like 5G antenna patterns
- EPFD and link degradations with rain statistics included
- Wide-area 5G deployment impacts

27 June 2017

5G “Omni”-like Antenna Patterns and Assessment

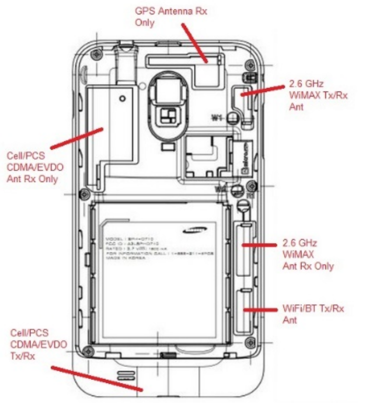
- **EPFD approach uses directional antenna gain patterns to correctly model interference into receivers**
- **But any interference calculation (including EPFD) relies on the peak gain to determine the actual noise floor impact**
- **Broad beam antenna patterns (*i.e.,* near “omni-” directional cases) have very low peak gain (0-6 dBi). This is 10 dB to 20 dB (10 to 100 times) lower gain than a typical UE, CPE, or base station**
- **Thus, even if many (or hundreds) more interferers could appear in the main beam, the <u>impact on system noise floor will be approximately the same</u>**
- **Use of low-gain or “omni” directional type antennas in mmW bands is inconsistent with efficient spectrum usage and the goals of 5G service**

5G handset model (Boeing Dec 2016 Ex parte)



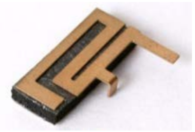
Array configuration	Peak Gain (dBi)	99.5% degradation with mispointing
1x4 (top/bottom)	10-11 dBi	0.2-0.25 dB
1x8 (sides)	13-14 dBi	0.35-0.45 dB
4x8 (front/back panels)	19 dBi	0.65 dB

Galaxy S antennas (example)



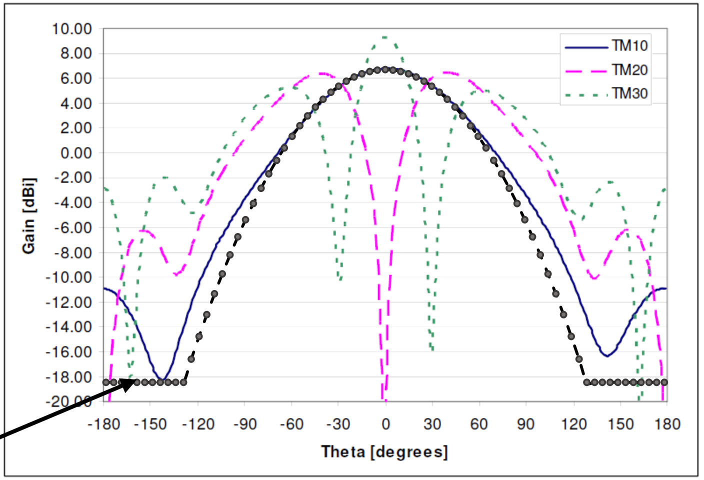
Whip

Microstrip patch



PIFA* (most common)

5G single-element Gain Models) (simulated patch and 3GPP element model)

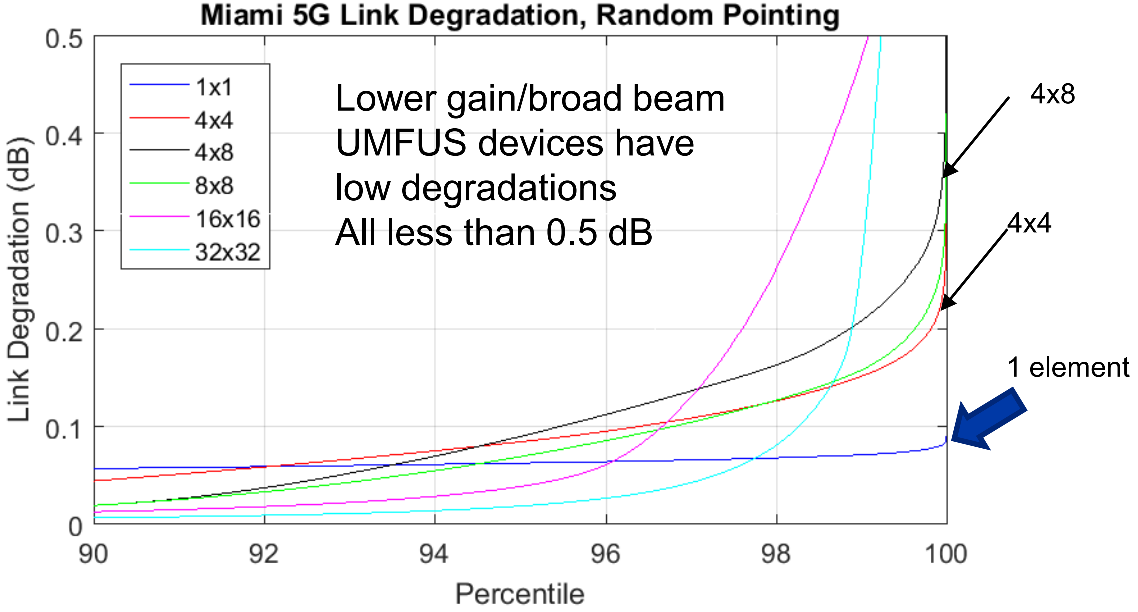


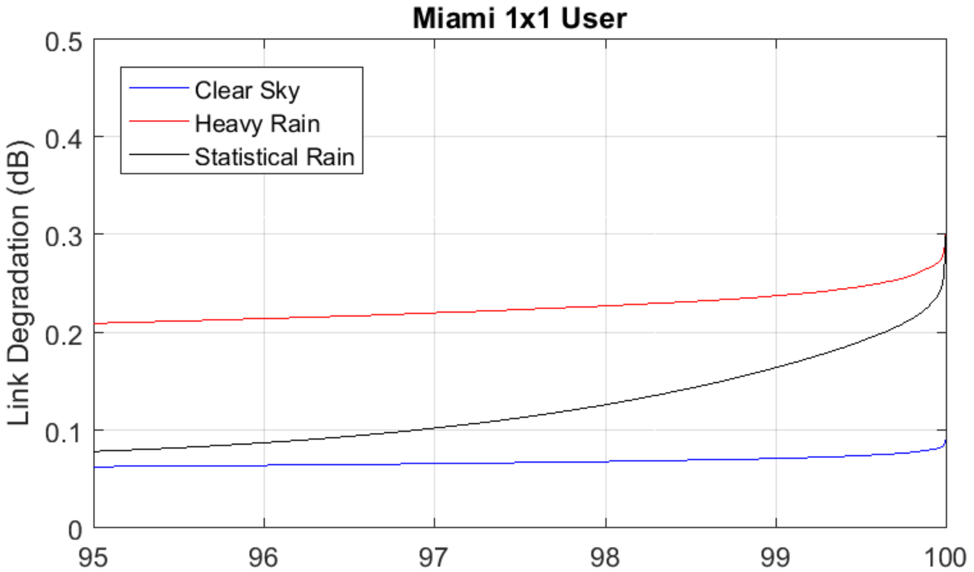
3GPP: 5 dBi peak gain 90-deg HPBW

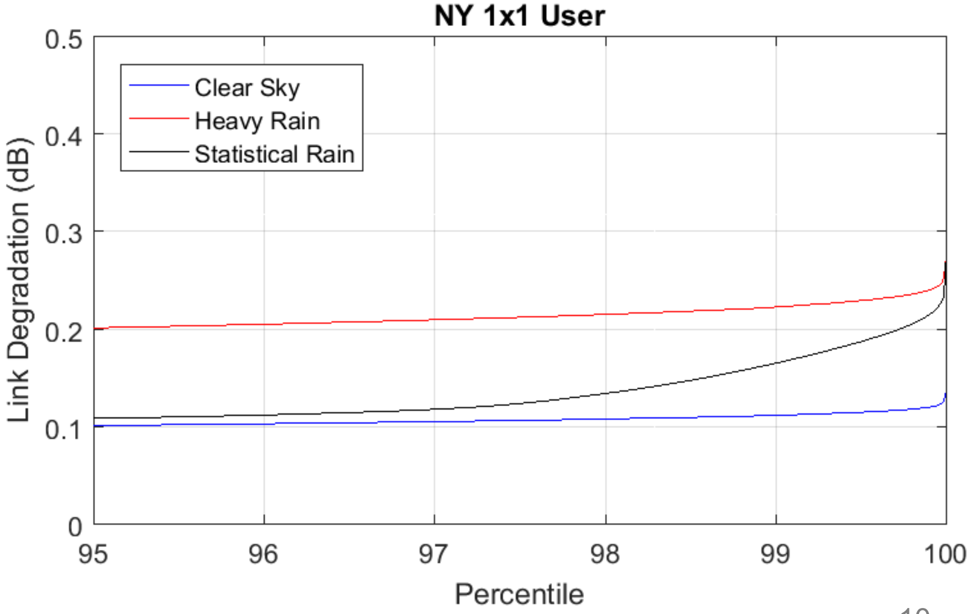
Peak Antenna Gain (dBi)	HPBW (deg)	Gain Decrease (x)	Notional Interference increase (x)	Expected Link degadation (dB)
13.0	90x12	0.25	4.0	0.50
10.0	90x23	0.13	8.0	0.50
8.0	65	0.08	16.7	0.65
5.0	90	0.04	32.0	0.63
2.2	180	0.02	32.0	0.34

3GPP TR 38.802 Study on New Radio Access Technology Physical Layer Aspects (Release 14) v14.10 June 2017 Tables A.2.1-6 and A.2.1-8

“Omni”-like UMFUS Receiver – Statistical EPFD Results







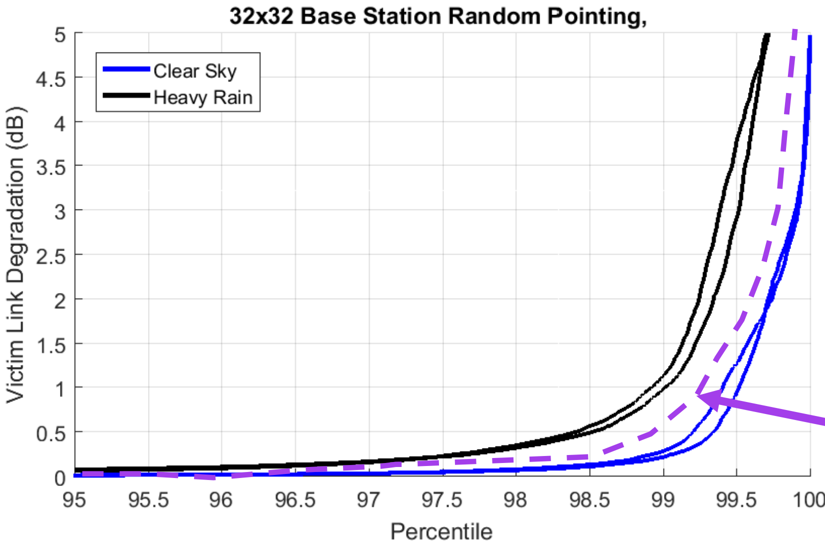
Link degradation of an omni or omni-like receiver is flat with minimal degradations (<0.1-0.3 dB)

Modeling of Clear-Sky, Rain Fade, and Probability of Degradation

- **To date, Boeing has submitted "separate" interference assessments for clear sky & heavy rain fade conditions**
- **Separate assessments are based on the current FCC PFD regulations, which have separate allowable PFD levels (25.208(r)(1) vs 25.208(r)(2)**
- **To compute actual system availability and capacity impacts, a combined probability of interference level including the probability of rain fade is needed**
  - Budgets shown to the right previously submitted in FNRPM reply comments illustrate this approach
- **Results shown in the following slides measure FSS interference link degradations into UMFUS under all three conditions**
  - Clear Sky, Heavy Rain, and Combined (overall probability)
- **All other conditions remain the same, including the "victim" 5G receiver receiving signals in clear-sky (free space losses only)**

Notional system capacity Impact (FNPRM Reply Comments and Boeing Dec 2016 ex parte)

PARAMETER	UNITS	I/N=-8	I/N=-6	COMMENT
Link degradation due to satellite interference	dB	0.65	1.0	Rise in noise floor, satellite in view in heavy rain fade
Probability of satellite interference (as calculated in heavy rain fade)	%	1.0%	1.0%	99% of the time the degradation is less than above
Probability of rain fade	%	10.0%	10.0%	90% of the time it is NOT raining
Total Probability of degradation event	%	0.10%	0.10%	Total % of time degradation may exist
Nominal spectral efficiency (no interference)	bps/Hz	2.0	2.0	Average - can be lower or higher
Capacity decrease due to degradation	%	7.9%	12.1%	During the transient ONLY, at certain spots with high rain
Total system capacity impact	%	0.0079%	0.0121%	Very small
Percent of design capacity achieved	%	99.992%	99.988%	Very high

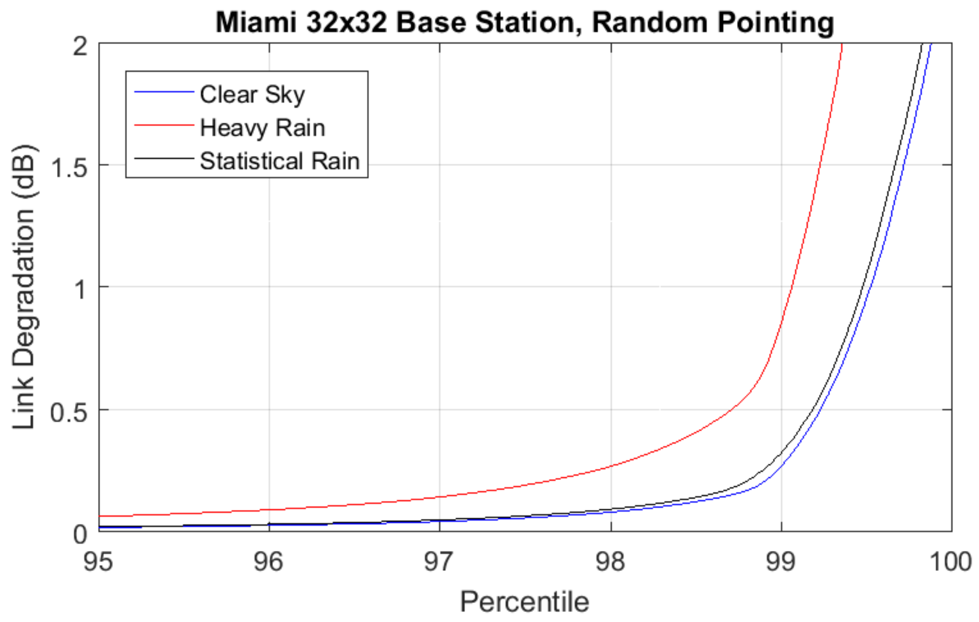


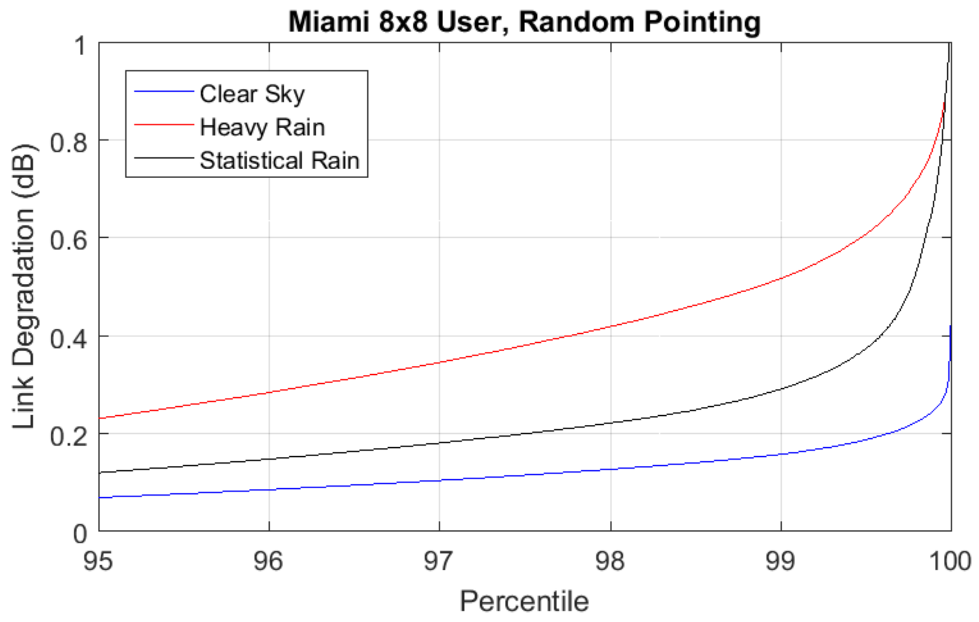
Clear sky (corresponds to 25.208(r)(1) PFD compliant operations)

Heavy Rain appears to be "worse" – but this is a conditional probability assuming rain – the rain fade availability itself is not included in the percentiles

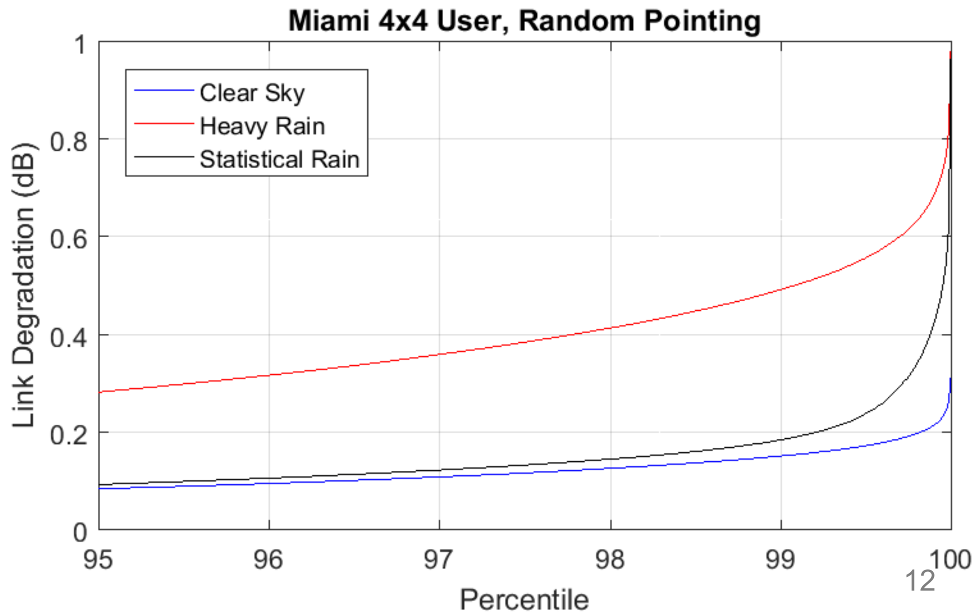
Adjusted curves with a combined total probability will show degradations have lower overall time of occurrence (closer to clear sky performance)

EPFD and Link Degradation with Rain Statistics

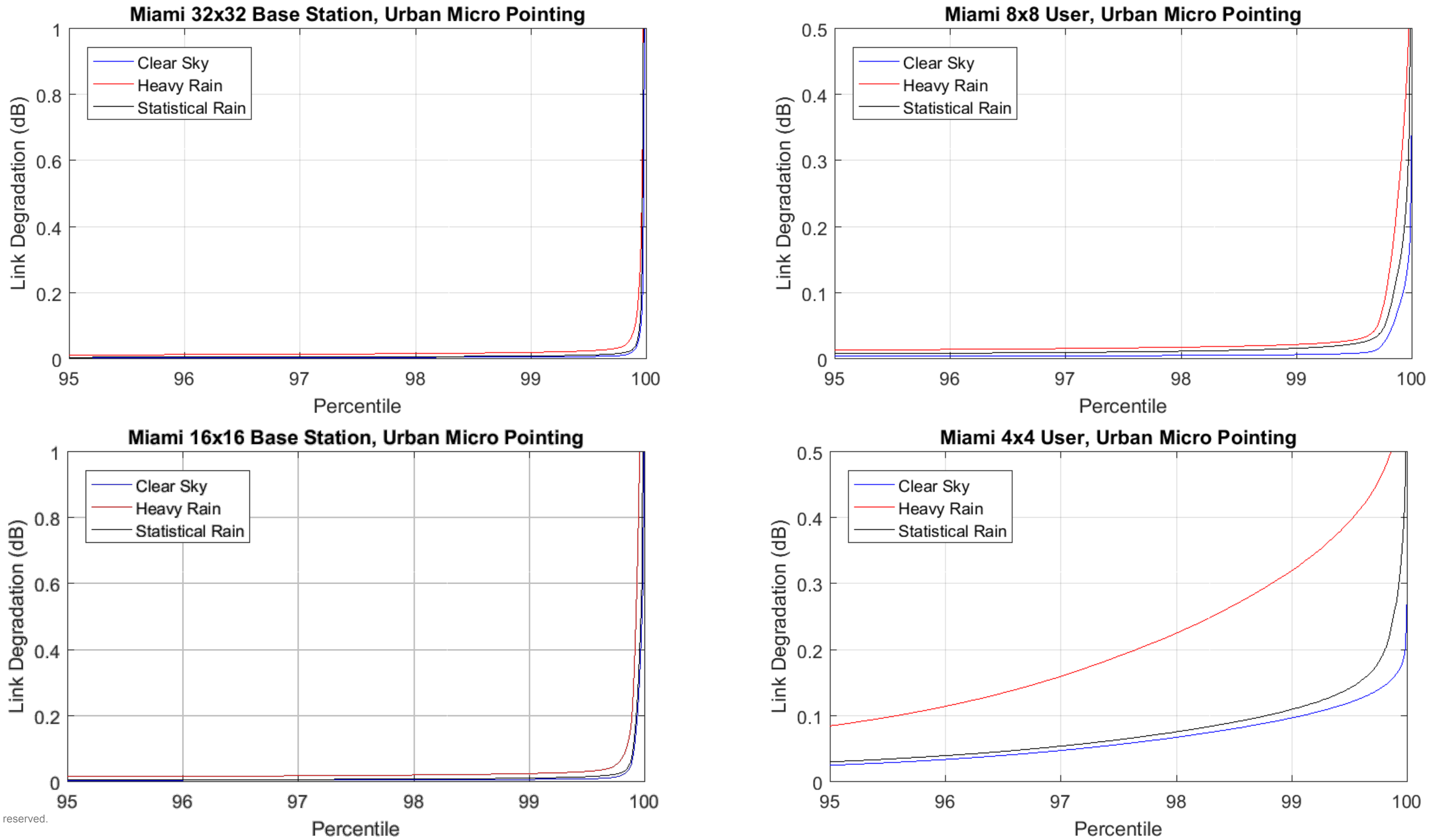




High Rain-Fade Weather Events and Line-of-Sight Conjunction Events are Extremely Rare



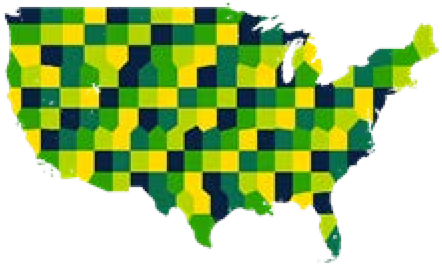
EPFD and Link Degradation with Rain Statistics



Impact on 5G Deployments – Approach

- **158 Rain CONUS Regions, each with its own:**
  - Weather
  - Spacecraft line-of-sight geometry
- **Each region considered using each of the four UMFUS deployment scenarios, *i.e.*, Rural Macro (5km), Rural Macro (2km), Urban Macro, and Urban Micro pointing**
  - Urban scenarios assume use of 16x16 base station gain patterns and rural scenarios assuming 32x32 base station gain patterns
- **Resulting 632 cases (158 rain regions each with four deployment scenarios) weighted for 5G user population**
- **The average of the population-weighted results is the expected link degradation to a CONUS-wide deployment of 5G Base Stations**
  - Capacity degradation is based on Shannon limit

Rain Region Grid



Total Population

5km Rural Macro

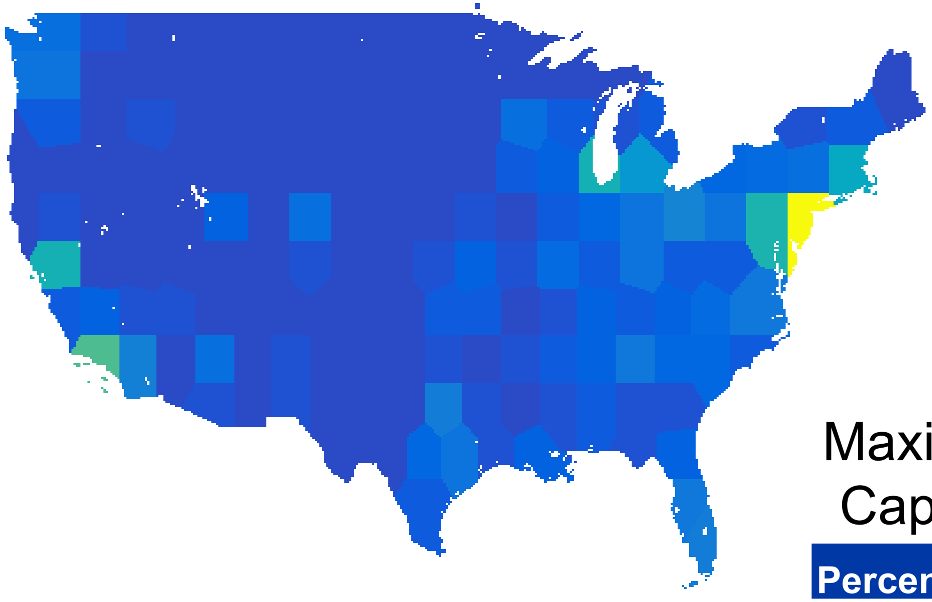
2km Rural Macro

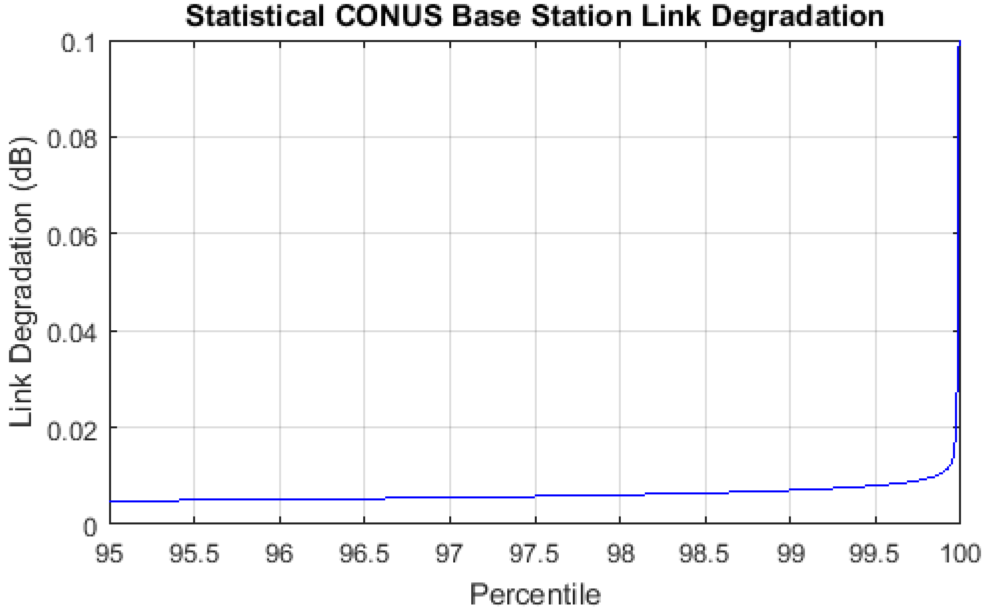
Urban Macro

Urban Micro

CONUS Wide 5G Deployment Impacts

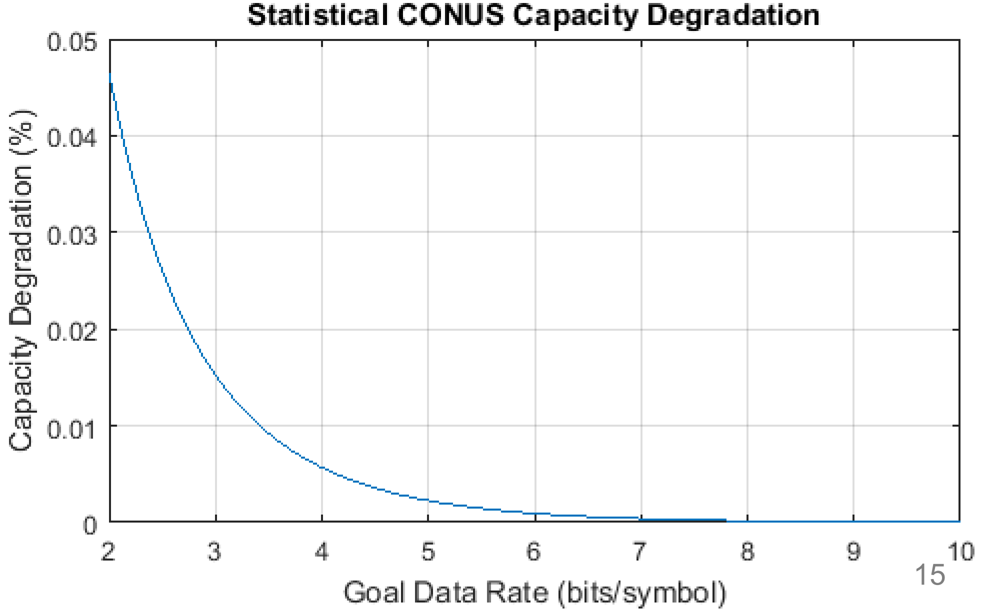
CONUS Capacity Degradation





Maximum Base Station Capacity Degradation

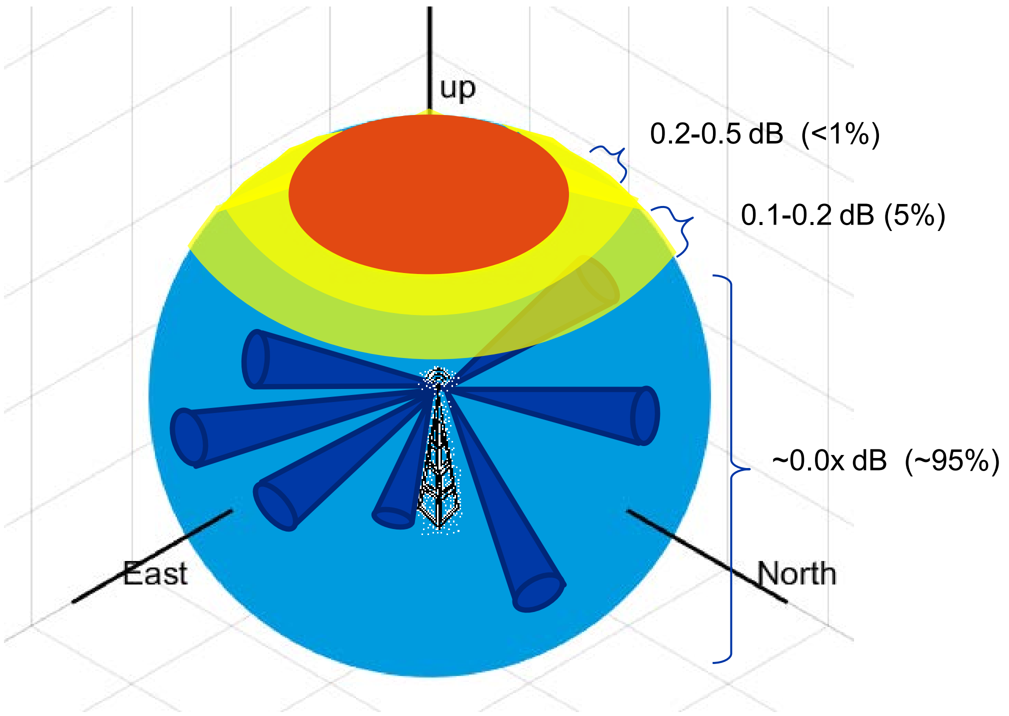
Percentile	Degradation (%)
90	0.031
95	0.038
99	0.058



High-Degradation events are rare and do not constitute what an “average” user would experience

Base Station Capacity Impact – Multiple Beams

- **FSS-UMFUS interference modeling generates the probability of interference into a single base station beam steered over the relevant volume (random pointing or cellular pointing at users)**
- **The probability that this beam experiences a given interference level is given by the pdf/cdf's measured**
- **A base station using M beams ("MIMO") experiences interference into each beam at the same rate**
- **The interference occurs "M" times more often in total**
- **<u>But</u> the base station has "M" times the capacity when compared to one beam operation**
- **The relative capacity degradation due to FSS interference (which is a percentage of the total designed capacity) remains the same**



If a link degradation has a probability of <1% of occurrence to one beam, it occurs 1% of the time over all beams (regardless of number of operating beams)

Capacity degradation as a fraction of the base station's total capacity is the same for one beam or multiple beams

FSS 37/39 GHz Sharing with UMFUS

- EPFD regulatory framework for UMFUS - updates

27 June 2017

FCC Satellite Downlink PFD Regulations in 37/39 GHz and Possible Framework for FSS UMFUS EPFD Regulations

- **25.208(q)(1) – GSO PFD in Clear Sky**
  (-117 dBW/m2/MHz)
- **25.208(q)(2) – GSO PFD during rain-fade**
  (-105 dBW/m2/MHz)
  + **NOTE to PARAGRAPH (q) – Conditions for PFD in heavy rain**
- **25.208(r)(1) – NGSO PFD in Clear Sky**
  (-117 dBW/m2/MHz)
- **25.208(r)(2) – NGSO PFD during rain-fade**
  (-105 dBW/m2/MHz)
  + **NOTE to PARAGRAPH (r) – Conditions for PFD in heavy rain**

- **No Change**
- **No Change**
- **Add 25.208(q)(3) – GSO Clear sky EPFD masks OR update PFD mask in rain**
- **No Change**
- **No Change**
- **Add 25.208(r)(3) – NGSO+GSO Clear sky and Rain fade EPFD masks**

- ***EPFD regulations for combined FSS interference during rain are ready for consideration***

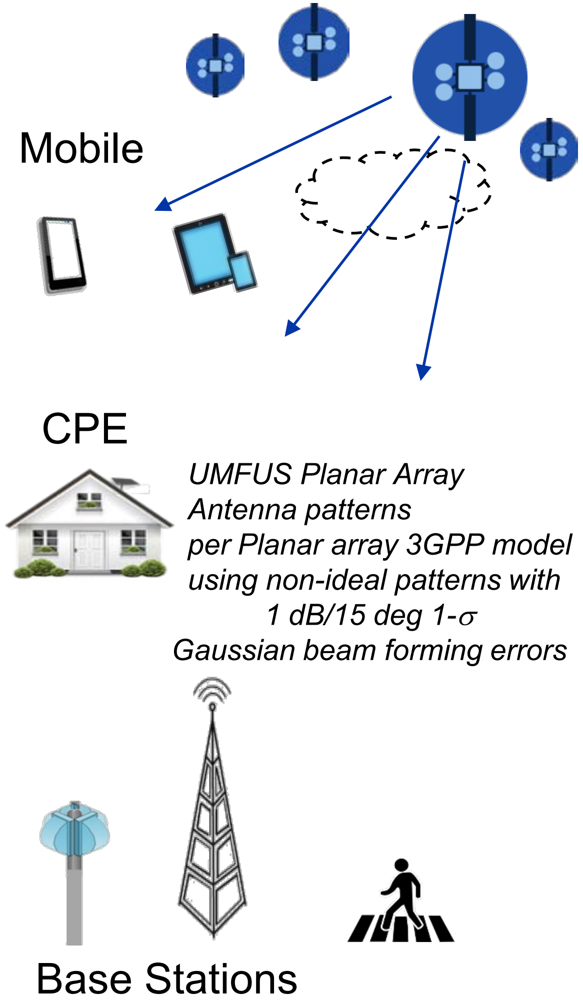
EPFD Regulations can Cover a Broad Range of UMFUS Devices and Pointing Conditions

NGSO Constellation ePFD into UMFUS Devices	Potential Pointing Cases
UMFUS mobile UE 4x4 planar array, *G_{pk}=16 dBi, NF=7 dB 4x8 planar array, *G_{pk}=19 dBi, NF=7 dB	• Mispointed at a satellite • Cellular pointed
UMFUS transportable / CPE 8x8 planar array, *G_{pk}=22 dBi, NF=7 dB Array orientation 0-deg tilt (horizontal) Random electronic steering over +/- 60 deg radial angle (half-cone angle)	• Random electronic steering • Cellular pointing with limited electronic scan
UMFUS base station 16x16 planar array, *G_{pk}=27 dBi, NF=5 dB 32x32 planar array, *G_{pk}=33 dBi, NF=5 dB Array orientation 0-deg tilt (horizontal) Random electronic steering over +/- 60 deg radial angle (half-cone angle)	• Random electronic steering OR • Cellular pointed (UMi and UMa cases)

(for information only – noise figure etc. is not part of ePFD regulations)*

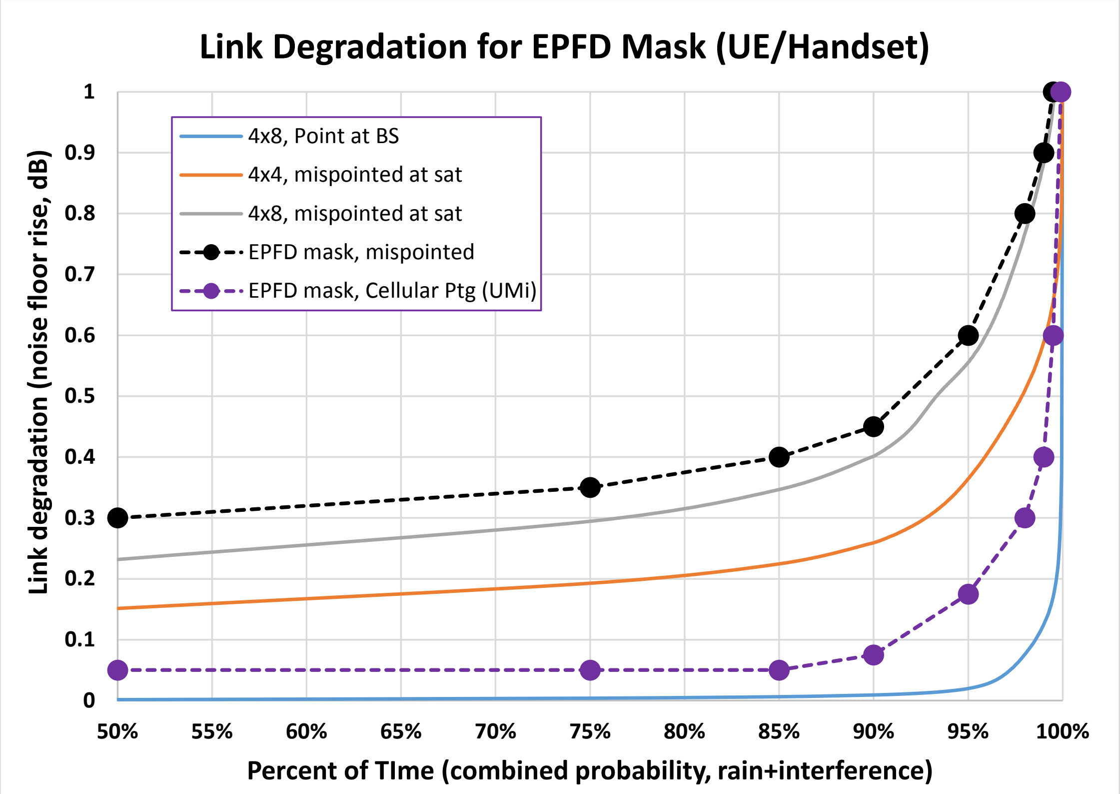
EPFD Regulation Format
Multi-point EPFD Mask
(one table per each case)

Percent of time EPFD is NOT exceeded	EPFD (dBW/m2/MHz)
50.0%	-122.1
75.0%	-122.1
85.0%	-122.1
90.0%	-120.3
95.0%	-116.6
98.0%	-114.2
99.0%	-112.9
99.5%	-111.0
99.9%	-108.6



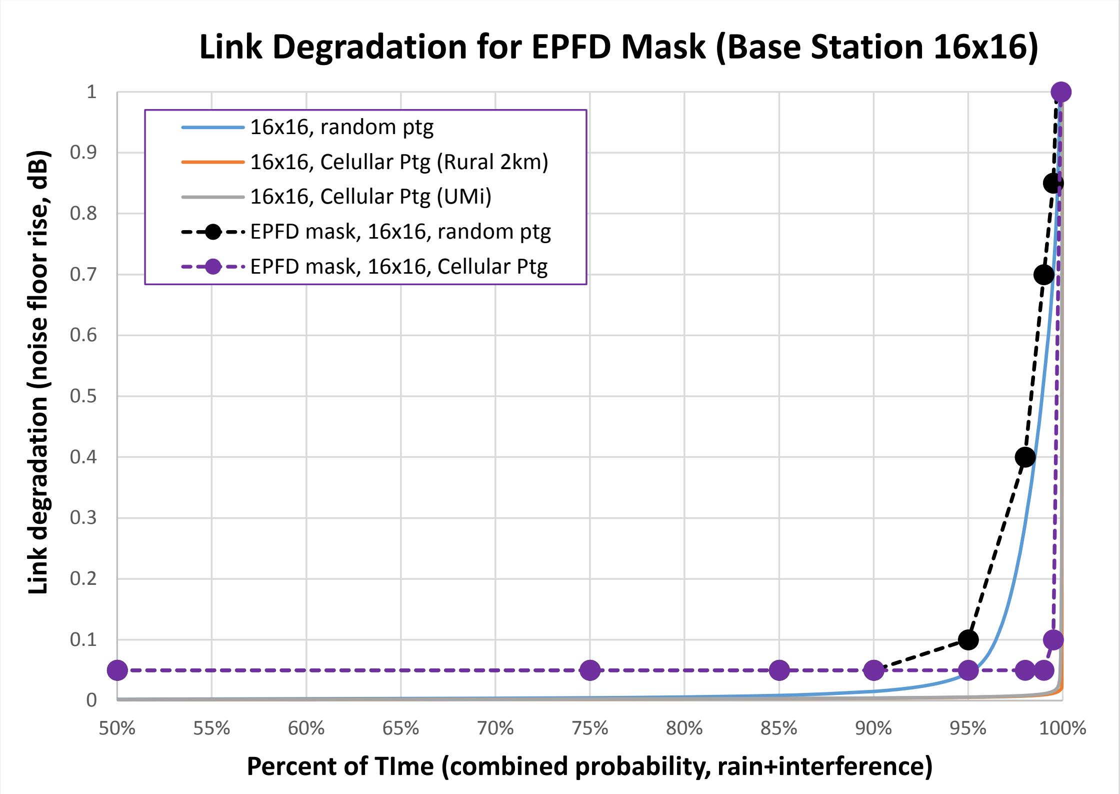
NGSO ePFD regulations augmenting 25.208(r) are ready for consideration

Example Link Degradations due to EPFD Masks



Less than 0.5% system capacity degradation in all cellular pointing cases

System capacity degradation to the handset can be eliminated if base station provides less than 1 dB additional EIRP less than 5% of the time



EPFD masks can be adopted that provide high confidence and regulatory certainty for UMFUS deployments

Summary – 37/39 GHz Spectrum Sharing with NGSO FSS

- **EPFD approach correctly predicts FSS-UMFUS interference**
- **Comprehensive multipath modeling uses complete and broadly representative scenarios with full range of building densities**
  - Accurate model, few/no approximations, minimal statistical impacts seen due to reflections
- **EPFD results include all radiated beams from all satellites above the horizon**
- **Interference into “omni” type receive elements maintained at low level due to their low gain**
- **Interference levels using combined total probability of interference (including rain availability) demonstrate the extremely low impacts to 5G capacity**
  - Well below 1% capacity impact due to FSS satellite band sharing
- **EPFD regulatory framework is appropriate for update of FSS PFD regulations in the 37/39 GHz band – values for EPFD “masks” are ready for consideration**